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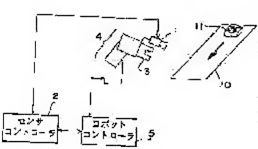
(54) ROBOT DEVICE AND ITS CONTROL METHOD



(57)Abstract:
PROBLEM TO BE SOLVED: To save labor for troublesome teaching work and calibration and allow easy work for objects, as predetermined.
SOLUTION: In teaching work, a robot controller 5 stores a position Pd of a gripper 3 in the state of gripping the object 11 and further stores any position (Ps) after the object 11 is released. In clamping work, the robot controller 5 makes the gripper 3 follow the object 11 being carried, go to the object 11 in accordance with the positions Ps, Pd and grip the object 11.

CLAIMS

[Claim(s)]

[Claim 1]A robot device which grasps a subject which exercises relatively, comprising:

A holding means which has a gripping mechanism which grasps said subject and said gripping mechanism comprised movable.

An imaging means which is fixed movable with a gripping mechanism of said holding means, and picturizes a subject.

A feature amount extracting means which extracts coordinates of one or more characteristic quantity from a picture of a subject which said imaging means picturized.

A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when moving said gripping mechanism within limits which can make said subject able to open wide and in which said imaging means can picturize a subject is memorized as the 2nd end point position, A memory measure which memorizes coordinates of each characteristic quantity of said subject which said imaging means picturized in said 2nd end point position, and said feature amount extracting means extracted.

A calculating means which computes a move procession for moving from said 2nd end point position to said end point position of 1.

A follow-up control means by which coordinates of each characteristic quantity of a subject under movement extracted by said feature amount extracting means carry out control which said gripping mechanism is made to follow to a subject under said movement by moving said holding means so that it may be in agreement with coordinates of each characteristic quantity memorized by said memory measure.

A grasping control means which controls said holding means to bring said gripping mechanism close to a subject under said movement based on a move procession which said calculating means computed, and to make said subject grasp when a subject while said gripping mechanism is exercising is followed.

[Claim 2]While said gripping mechanism separates said memory measure prescribed distance to a subject under said movement by said follow-up control means, when it follows, Coordinates of each characteristic quantity of said subject which said feature amount extracting means extracted are newly memorized, The robot device according to claim 1 which memorizes a position of said gripping mechanism when said follow-up control means makes said gripping mechanism follow a subject thoroughly from said 2nd end point position using coordinates of each newly memorized characteristic quantity as the 2nd new end point position.

[Claim 3]In a control method of a robot device which grasps a subject which exercises relatively by a gripping mechanism constituted movable, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when making said subject open wide and moving said gripping mechanism within limits which can picturize a subject is memorized as the 2nd end point position, In said 2nd end point position,

picturize said subject, and coordinates of one or more characteristic quantity are extracted from a picture of said picturized subject, In the state where memorized coordinates of each of said extracted characteristic quantity, computed a move procession for moving from said 2nd end point position to said end point position of 1, and it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Coordinates of each characteristic quantity of a subject under said extracted movement by moving said gripping mechanism so that it may be in agreement with coordinates of each of said characteristic quantity memorized. When said gripping mechanism is made to follow a subject under said movement and a subject while said gripping mechanism is exercising is followed, based on said computed move procession, said gripping mechanism is brought close to a subject under said movement, A control method of a robot device of making said gripping mechanism grasping said subject.
[Claim 4]While said gripping mechanism is made to follow a subject under said movement, and said gripping mechanism separates prescribed distance to a subject under said movement, when it follows, in the state where it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Newly memorize coordinates of each characteristic quantity of said said extracted subject, and coordinates of each of said newly memorized characteristic quantity are used, A control method of the robot device according to claim 3 of memorizing a position of said gripping mechanism as the 2nd new end point position when said gripping mechanism is moved so that said gripping mechanism may follow a subject thoroughly from said 2nd end point position, and followed thoroughly.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to a robot device and a method for controlling the same, and relates to a robot device which grasps the object under movement especially, and a method for controlling the same.
[0002]
[Description of the Prior Art]When working to a subject using a robot (for example, objective grasping), information, including the position of a subject, a posture, etc., is acquired by a sensor, and many examples which work based on the sensor information are put in practical use. As such an equipment configuration, it divides roughly and, generally there are the following two methods.
[0003]For example, there are some which detect the position of a subject and a posture from the picture acquired by picturizing with the camera which had the subject which has a conveyor top conveyed fixed, and transmit the information to a robot as indicated to JP,8-63214,A. This robot is working grasping etc. from the position information on a subject.
[0004]Sensors, such as a camera, are attached to the hand of a robot, the target positional attitude is detected from the picture from a camera as mentioned above, and there are

some which follow the subject which moves based on the information, and work grasping etc.
[0005]
[Problem(s) to be Solved by the Invention]However, when realizing the work of grasping of a subject, etc. using the camera installed apart from the robot like the former, the work which asks for the installed position of a robot and a camera correctly beforehand is needed. It is necessary to perform the camera calibration which computes a focal distance, a lens strain coefficient, etc. of the camera beforehand.
[0006]In addition, in the example in JP,8-63214,A etc., it is necessary to install so that the optic axis of a camera may generally become vertical still more nearly parallel to the transportation direction of a conveyor at a conveyor flat surface in the x axis or the y-axis in a screen. Since the subject is running by the band conveyor etc., in addition to the position attitude information of the subject detected by the picture from a camera, another means (for example, encoder of a conveyor) needs to detect the speed information of a conveyor, etc., and it is necessary to generate the command value to a robot based on both information. The orbit at the time of a robot grasping a subject from the installation position information of a camera and a robot, the position information on a subject, and the speed information of a conveyor must be generated. Therefore, there are problems, like the procedure for teaching work and trajectory generation becomes very complicated.
[0007]It can say such a problem that the same may be said of the example of the latter which installed the camera to the hand of the robot in conventional technology. That is, when a subject is grasped by the gripper etc. which were attached to the hand of a robot based on the position attitude information of the subject detected from the picture from a camera, What is called a hand eye calibration that needs to change the position attitude information of the subject acquired from the camera into the position attitude information seen from the standard coordinates of the robot, and searches for the physical relationship of a robot hand and a camera precisely beforehand is needed. When sensors, such as a camera, are especially installed in a robot hand, a camera position relation with a robot hand frequently changes with the malfunctions under work, etc., and it is necessary to do calibration work again in that case. When the subject is moving like the former example, since the position attitude information of the subject seen from the robot normal coordinate changes every moment, it becomes very complicated [the trajectory generation for grasping].
[0008]In the former, even if the method of the former and the latter changes neither a component (the installation condition of a conveyor, a bearer rate, or the installed position relation between a camera and a robot), nor the shape of a subject which should be grasped, Whenever the robot and sensor to be used changed, the above-mentioned highly precise calibration and complicated teaching work needed to be performed.
[0009]This invention is proposed in order to cancel the problem mentioned above, and it is a thing.
The purpose is to provide a robot device which can save the time and effort which performs work and a calibration, and can make predetermined work do on a subject easily, and a method for controlling the same.

[0010]
[Means for Solving the Problem]A holding means from which the invention according to

claim 1 has a gripping mechanism which grasps a subject and which said gripping mechanism comprised movable, An imaging means which is fixed movable with a gripping mechanism of said holding means, and picturizes a subject, A feature amount extracting means which extracts coordinates of one or more characteristic quantity from a picture of a subject which said imaging means picturized, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when moving said gripping mechanism within limits which can make said subject able to open wide and in which said imaging means can picturize a subject is memorized as the 2nd end point position, A memory measure which memorizes coordinates of each characteristic quantity of said subject which said imaging means picturized in said 2nd end point position, and said feature amount extracting means extracted, A calculating means which computes a move procession for moving from said 2nd end point position to said end point position of 1, Coordinates of each characteristic quantity of a subject under movement extracted by said feature amount extracting means by moving said holding means so that it may be in agreement with coordinates of each characteristic quantity memorized by said memory measure. When a follow-up control means which carries out control which said gripping mechanism is made to follow to a subject under said movement, and a subject while said gripping mechanism is exercising are followed, Based on a move procession which said calculating means computed, said gripping mechanism is brought close to a subject under said movement, and it has a grasping control means which controls said holding means to make said subject grasp.
[0011]The robot device according to claim 1 grasps a subject which exercises relatively to the robot device concerned. Therefore, a case where said robot device exercises and said subject is being fixed, when said robot device and said subject are exercising at a speed different, respectively, and not only when said robot device is fixed and said subject exercises, but when, it can apply. Although said subject may be carrying out the acceleration straight-line motion of linear uniform motion, the uniform circular motion, etc. relatively to said robot device, it may be standing it still relatively.
[0012]First, the operator needs to perform the following two things as teaching work. A gripping mechanism is moved to the 1st end point position, and a subject is made 1st to grasp here. A subject is made to release from a gripping mechanism and an imaging means moves [2nd] a gripping mechanism within limits which can picturize a subject to the 2nd end point position. Such teaching work is performed and a memory measure is made to memorize the 1st and 2nd end point positions. A memory measure is made to also memorize coordinates of one or more characteristic quantity extracted from a picture which an imaging means picturized in the 2nd end point position. An imaging means serves as a sensor of a gripping mechanism, and it is being fixed so that it may move with a holding means. A move procession for moving from the 2nd end point position to the 1st end point position is computed.
[0013]If such teaching work is completed, grip operations which grasp a subject under movement can be performed. A gripping mechanism is moved so that coordinates of each characteristic quantity of a subject under movement may be in agreement with coordinates of each characteristic quantity memorized by said memory measure. That is, what is called a visual servo is performed so that a subject while a gripping mechanism is exercising may be followed. Relative physical relationship of a subject at this time and a

gripping mechanism is the same as a subject at the time of teaching work, and that relative of a gripping mechanism. When a subject while said gripping mechanism is exercising is followed, based on the 1st move procession that said calculating means computed, said gripping mechanism is brought close to a subject under said movement, and said subject is made to grasp.

[0014]It is desirable for a gripping mechanism to follow a subject under movement thoroughly in a case where a visual servo is being performed. However, a gripping mechanism may follow, separating prescribed distance to a subject under movement. In such a case, it is preferred that re-teaching work which is indicated to claim 2 is performed. While said gripping mechanism separates said memory measure prescribed distance to a subject under said movement by said follow-up control means, when it follows, specifically, Coordinates of each characteristic quantity of said subject which said feature amount extracting means extracted are newly memorized, What is necessary is just to memorize a position of said gripping mechanism when said follow-up control means makes said gripping mechanism follow a subject thoroughly from said 2nd end point position using coordinates of each newly memorized characteristic quantity as the 2nd new end point position.

[0015]The invention according to claim 3 is the control method of a robot device which grasps a subject by a gripping mechanism constituted movable, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when making said subject open wide and moving said gripping mechanism within limits which can picturize a subject is memorized as the 2nd end point position, In said 2nd end point position, picturize said subject, and coordinates of one or more characteristic quantity are extracted from a picture of said picturized subject, In the state where memorized coordinates of each of said extracted characteristic quantity, computed a move procession for moving from said 2nd end point position to said end point position of 1, and it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Coordinates of each characteristic quantity of a subject under said extracted movement by moving said gripping mechanism so that it may be in agreement with coordinates of each of said characteristic quantity memorized. When said gripping mechanism is made to follow a subject under said movement and a subject while said gripping mechanism is exercising is followed, based on said computed move procession, said gripping mechanism is brought close to a subject under said movement, Said gripping mechanism is made to grasp said subject.

[0016]This invention is a method for controlling a robot device indicated to claim 1, and the operator should just perform two things mentioned above as teaching work. That is, only by an operator performing two easy teaching work, a gripping mechanism can be made to be able to follow a subject which is exercising and the subject can be grasped.

[0017]It is desirable for a gripping mechanism to follow a subject under movement thoroughly in a case where a visual servo is being performed. However, a gripping mechanism may follow, separating prescribed distance to a subject under movement. In such a case, it is preferred that re-teaching work which is indicated to claim 4 is performed. While said gripping mechanism specifically separates prescribed distance to a subject under said movement, when it makes said gripping mechanism follow a subject

under said movement, and it follows, it is in a state fixed movable with said gripping mechanism, Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Newly memorize coordinates of each characteristic quantity of said said extracted subject, and coordinates of each of said newly memorized characteristic quantity are used, What is necessary is just to memorize a position of said gripping mechanism as the 2nd new end point position, when said gripping mechanism is moved so that said gripping mechanism may follow a subject thoroughly from said 2nd end point position, and followed thoroughly.
[0018]
[Embodiment of the Invention]Hereafter, it explains in detail, referring to drawings for an embodiment of the invention.
[0019](A 1st embodiment) As shown in drawing 1, the robot device concerning this embodiment grasps the subject 11 currently conveyed by conveyor 10 in the state where it was fixed. This invention is not limited to such an embodiment, and if the subject 11 is exercising relatively to a robot device, it is applicable. That is, they may be a case where a robot device exercises and the subject 11 is standing it still, and a case where it is exercising at the speed from which a robot device and the subject 11 differ. 2nd and 3rd embodiments are also the same.
[0020]A robot device is provided with the following.
CCD camera 1 which picturizes the subject 11.
The sensor controller 2 which extracts characteristic quantity from the picture which CCD camera 1 picturized.
The gripper 3 which grasps the subject 11.
The robot controller 5 which performs the robot arm 4 which moves the gripper 3 in the direction of a three dimension, coordinate conversion, trajectory generation, etc., has a servo circuit, amplifier, etc. which are not illustrated, and controls operation of the gripper 3 or the robot arm 4.

[0021]CCD camera 1 has adhered near the gripper 3 which is a tip of the robot arm 4. The robot controller 5 computes error vector E (t) and the speed commanding value vector V (t) based on the image characteristic quantity Fi obtained with the sensor controller 2, and controls movement of the robot arm 4, and grasping of the subject 11 by the gripper 3 according to these values. The conveyor 10 conveys the subject 11 at a fixed speed.
[0022]Before the robot device of such composition actually grasps the subject 11 currently conveyed, teaching work for grasping the subject 11 is performed.
[0023](Teaching work) First, an operator makes a robot device grasp the subject 11, and teaches the robot end point position P. The position which should be grasped may be restricted by the shape of gripping mechanisms, such as the gripper 3, and the subject 11. The position which should be grasped for next processing (for example, attach other parts to the subject 11, or supply to a parts box) may be specified beforehand.
[0024]Here, as shown, for example in drawing 2, the subject 11 was formed in 7 prismatic forms, and is provided with the seven sides 111-117. Six attachment holes (for example, tapped hole) for attaching the parts which are not illustrated are formed in the upper surface 118 of the subject 11. Such an attachment hole is not formed in the

undersurface 119 of the subject 11. As for the portion by which the subject 11 is grasped, it is preferred that they are the side 111,115 in which it faces among seven sides in consideration of stability when grasped, or the side 113,116. Although the subject 11 of the above-mentioned shape was used in this embodiment, this invention may not be limited to this shape and the subjects 11 may be other shape. And teaching work is specifically performed according to processing of step ST1 to step ST6 shown in drawing 3.

[0025]In step ST1, an operator shifts to step ST2, as the gripper 3 grasps the side 111,115 or the side 113,116 of the subject 11 using the teaching pendant etc. which are not illustrated.

[0026]In step ST2, as shown in drawing 4, the gripper 3 is in the state which grasped the subject 11, and the robot controller 5 memorizes, the position, i.e., robot end point position Pd, of the gripper 3 in robot standard coordinates, and shifts to step ST3. The "position" said here is expressed with the parameter of 6 flexibility including a posture. The parameter of 6 flexibility including a posture is called "position" like the following.

[0027]In step ST3, the robot controller 5 makes the subject 11 which the gripper 3 grasped release, and moves the gripper 3 to arbitrary positions, and shifts to step ST4.

[0028]It requires that the position which the gripper 3 moves is in the visual field range of CCD camera 1. That is, it is a position where the characteristic quantity of the subject 11 is extracted from the picture picturized with CCD camera 1. It is a position where characteristic quantity which should be extracted, such as a position to which the subject 11 is not settled in the view of CCD camera 1, and a position in which CCD camera 1 picturizes the subject 11 from just beside, is specifically suitably obtained from a picture.

[0029]In step ST4, the robot controller 5 memorizes, as shown in drawing 5, the position Ps, i.e., the robot end point position, of the gripper 3 in the present robot standard coordinates, and it shifts to step ST5.

[0030]Here, the following formulas will be realized if the positional attitude transformation matrix for changing into Pd from the robot end point position Ps is made into P_O.

[0031]Ps-P_O=PdthereforeP$_O$=Ps^{-1} and the Pd robot controller 5 compute positional attitude transformation-matrix P_O at this time, and memorizes this. The robot controller 5 may compute positional attitude transformation-matrix P_O in the case of the grip operations mentioned later.

[0032]In step ST5, CCD camera 1 picturizes the subject 11 in the robot end point position Ps, and supplies this picture to the sensor controller 2. The sensor controller 2 extracts image characteristic quantity based on the picture from CCD camera 1, and shifts to step ST6. Here, CCD camera 1 acquires the picture of the subject 11 as shown, for example in drawing 6.

[0033]In step ST6, six attachment holes processed into the upper surface 118 of the subject 11 are extracted as the image characteristic quantity Fi (i= 1-6), the center position of each image characteristic quantity Fi carries out coordinate value (Xi, Yi) memory, and the sensor controller 2 ends processing of teaching work.

[0034]What is necessary is just to use publicly known techniques, such as binarization image processing and edge processing, as an instrumentation method of the center position of the attachment hole in a picture. Although it attached here and the center position of the hole was made into the image characteristic quantity Fi, the area center of

gravity of the isolated field of a line segment corner point, a corner, and a binarization picture, etc. may use other image characteristic quantity. An operator may give a definition artificially by the input means in which neither a mouse nor a keyboard illustrates the image characteristic quantity Fi at the time of instruction.
[0035](Grip operations) A robot device grasps the subject 11 under conveyance using the coordinates of the image characteristic quantity Fi memorized on the occasion of the work, and the robot end point positions Pd and Ps, after teaching work is completed. In these grip operations, processings from step ST11 to step ST18 shown in drawing 7 are performed.
[0036]In step ST11, as shown in drawing 8, CCD camera 1 picturizes a transportation area [of the subject 11] 10, i.e., conveyor, top, and shifts to step ST12.
[0037]In step ST12, the sensor controller 2 judges whether the subject 11 was detected. In order to detect the subject 11 and to extract characteristic quantity from the picture, it is required for the subject 11 whole to enter within the limits of the view of CCD camera 1. Here, the luminosity of a picture is used for detection of the subject 11. For example, when the subject 11 is upstream of the conveyor 10 and there is into the visual field range of CCD camera 1, the luminosity of the picture acquired with CCD camera 1 hardly changes. [no] On the other hand, if the subject 11 is conveyed by conveyor and it enters in the visual field range of CCD camera 1, the luminosity will change. Then, it judges with the sensor controller 2 providing the window which is not illustrated in the suitable position in a picture, and the subject 11 being in a visual field range, when the luminosity in the window is beyond a predetermined threshold, and when luminosity is less than a predetermined threshold, it judges with there being nothing within the limits of the view. And when the sensor controller 2 detects the subject 11, it shifts to step ST13, and when it does not detect, it returns to step ST11.
[0038]image-characteristic-quantity fi(t) (i=1 in the time T from a picture when CCD camera 1 picturized the sensor controller 2 in step ST13, and 2 ...) -- it extracts and shifts to step ST14. Here, drawing 9 is a figure showing the picture picturized at the time of execution of grip operations. It is necessary to extract the image characteristic quantity fi (t) from the picture picturized at the time t at the time of grip operations. However, there is a thing which should extract essentially by a certain cause and for which the image characteristic quantity f3 (t) is extracted for example, it does not come out. Then, the characteristic quantity f1 (t) - f7 (t) need to perform corresponding point searching which asks for any of F1 - F6 which show drawing 6 are supported.
[0039]This corresponding point searching can be performed with what is called checking methods, such as dynamic programming, a largest faction method, etc. which various methods are proposed, for example, are indicated to "robot vision" (Masahiko Yanaida work, Shokodo, 1990). If F1 - the thing corresponding to F6 are obtained out of f1-f7, the following image characteristic quantity can once be calculated easily.
[0040]What is necessary is just to specifically extract the image characteristic quantity fi (t+deltat) in the next time (t+deltat) of the time t near the image characteristic quantity fi in the inside of a previous picture (t), if cycle time of the repetition processings from step ST13 to step ST16 is set to deltat. Thereby, the stability of characteristic quantity extraction can ease increase and the burden of computation.
[0041]In step ST14, the sensor controller 2, It judges whether the error vector E (t) in the time t is small enough, or the judging standard of ||E(t) ||<epsilon is specifically met,

when small enough, it shifts to step ST17, and when not small enough, it shifts to step ST15.

[0042]Here, the error vector E (t) is searched for based on the image characteristic quantity fi (t) extracted from the picture of present CCD camera 1, and the image characteristic quantity Fi memorized by step ST6 mentioned above.

[0043]In this invention, literature B.Espiau et al., A New Approach to Visual Servoing in Robotics, IEEE Trans.Robotics and Automation, 8 (3), and 313-326-1992, Literature F.Bensalha et al. and Real Time Visual Tracking using the Generalized Likelihood Ratio Test,Int.Conf.Automation,Robotics and. Based on Computer Vision and the technique indicated to 1379-1383-1994, the error vector E (t) and the speed commanding value vector V (t) mentioned later are computed.

[0044]It asks for characteristic quantity deviation vector e (t) by the following formulas (1) using image-characteristic-quantity fi (t) = (Xi (t), Yi (t)) obtained from the picture picturized at image-characteristic-quantity Fi= at the time of instruction (Xi, Yi), and the time t.

[0045]

[Equation 1]

$$e(t)=\begin{pmatrix} x_1(t)-x_1 \\ y_1(t)-y_1 \\ x_2(t)-x_2 \\ y_2(t)-y_2 \\ \cdot \\ \cdot \\ x_N(t)-x_N \\ y_N(t)-y_N \end{pmatrix} \quad \cdots (1)$$

[0046](xi, yi) and (xi(t), and yi (t)) are expressed with a pixel value (Xi, Yi), and change (Xi(t) and Yi (t)) into the value in a camera coordinate system, respectively. N expresses the number of image characteristic quantity.

[0047]The error vector E (t) is expressed with a formula (2) using above-mentioned characteristic quantity deviation vector e (t).

[0048]

[Equation 2]

$$E(t)=L^{T+}e(t) \quad \cdots (2)$$

[0049]Here, L^{T+} is a false inverse matrix of picture Jacobian L^T calculated from the image characteristic quantity F and F (t).

[0050]It judges with the sensor controller 2 having followed the subject 11 which exercises, when the judging standard of ||E(t) ||<epsilon was met. epsilon is scalar quantity beforehand given by an operator. Or as long as it expresses E=(E1 E2 E3 E4 E5 E6) ^{T}, the judging standard shown in a formula (3) may be used.

[0051]

[Equation 3]

$$\max_i E_i < \varepsilon \quad \cdots (3)$$

[0052]In step ST15, the robot controller 5 computes the speed commanding value vector

V (t), and shifts to step ST16. The speed commanding value vector V contains the advancing-side-by-side speed (t_x, t_y, t_z) and revolving speed ($omega_x$, $omega_y$, $omega_z$) of the robot end point position P, It is expressed $V=(t_x t_y t_z omega_x omega_y omega_z)^T$. And the speed commanding value vector V (t+deltat) in time (t+deltat) is searched for from a formula (4).

[0053]

[Equation 4]

$$V(t+\Delta t)=-\lambda L^{T+}e(t)-\widehat{T^{0}(t)} \quad \cdots (4)$$

[0054]lambda is a speed gain. The rightmost paragraph of the right-hand side of a formula (4) is a point estimate of the motion velocity of the subject 11, and is searched for from a formula (5).

[0055]

[Equation 5]

$$\widehat{T^{0}(t)}=\frac{E(t)-E(t-\Delta t)}{\Delta t}-V(t) \quad \cdots (5)$$

[0056]The robot controller 5 computes error vector E (t) and the speed commanding value vector V (t) as mentioned above.

[0057]In step ST16, the robot controller 5 generates trajectory generation, and joint angular velocity and angular acceleration based on the computed speed commanding value vector V (t), controls the robot arm 4 according to these, and returns to step ST13.

[0058]In step ST17 when E (t) judges with it being small enough by step ST14, the robot controller 5 judges with the gripper 3 having followed the subject 11, and starts approach to the subject 11. In the following explanation, it is called visual servo by processing the flow chart shown in drawing 7 to make the gripper 3 follow a subject.

[0059]Here, if time which shifted to step ST14 is made into time t_1, as shown, for example in drawing 10, as for a speed commanding value vector, a position vector of V_{actual} (t_1) and a robot end point position will be set to P (t_1).

[0060]In time t_1, since the robot end point position P follows the subject 11, its speed commanding value vector V_{actual} at that time (t_1) is equal to a velocity vector of the subject 11. Therefore, the robot controller 5 generates a speed pattern on which a speed pattern for moving by P_O from the end point position P (t_1) was made to superimpose speed commanding value vector V_{actual} (t_1) mentioned above. P_O is the positional attitude transformation matrix shown by teaching work. A speed pattern for moving by P_O is computable with the conventional techniques, such as a trapezoid speed pattern, for example.

[0061]The robot controller 5 computes P_a according to the following formulas noting that it takes time T_O to carry out P_O part relative displacement.

[0062]

$P_a=P(t_1)+P_O+V_{actual}(t_1)$, T_O, and the robot controller 5 control the robot arm 4 based on computed P_a. Thereby, as shown in drawing 11, a robot hand (gripper 3) can be moved to position P_a which should grasp the subject 11 from the end point position P (t_1). After such approach is completed, it shifts to step ST18.

[0063]In step ST18, the robot controller 5 grasps the subject 11 by the gripper 3, and ends processing.

[0064]As mentioned above, the robot device can memorize the robot end point positions

Ps and Pd at the time of teaching work, and can follow the subject 11 under conveyance by a visual servo, and can perform grip operations of the subject 11 using the robot end point positions Ps and Pd. Thereby, the robot device can grasp the subject 11 under conveyance easily, without [without it is restrained by attitude position of the subject 11 under conveyance, and] stopping the conveyor 10.
[0065]Since work which searches for beforehand physical relationship the installed position, CCD camera 1, the gripper 3, and between subject 11 is unnecessary, the above-mentioned robot device, For example, even if it is a case where installation requirements of CCD camera 1 change, the subject 11 under conveyance can be grasped only by simple teaching work which was mentioned above. Even if it is a case where the subjects 11 which should be grasped differ when it is going to realize the same work by a different robot device, CCD camera 1, and the gripper 3, only simple teaching work is similarly.
[0066]Thereby, the operator can reduce load in the conventional teaching work and programming substantially. Even if change arises in CCD camera 1, the gripper 3, and the subject 11, it can respond flexibly.
[0067]In an embodiment mentioned above, although it mentioned as an example grasping the subject 11 currently conveyed by conveyor 10 and it was explained, a robot device can be made the same, also when grasping the stationary subject 11.Teaching work is the same as explanation mentioned above.
[0068]In grip operations, in step ST14 shown in drawing 7, when the error vector E (t) becomes small enough, the speed commanding value vector V (t) becomes zero, and speed V_{actual} (t_1) of a actual robot end point position becomes zero similarly.
[0069]Therefore, in step ST17, the robot controller 5 can grasp the subject 11 only using change part P_O of the present robot end point position P (t_1) and a position at the time of instruction. That is, position P_a which should be grasped is calculated by the following formulas.
[0070]P_a=P(t_1)+P_O and the robot controller 5 can control the robot arm 4 based on computed P_a, and can grasp the subject 11 stationary by the gripper 3.
[0071](A 2nd embodiment) Below, a 2nd embodiment of this invention is described. The same numerals are given to the same part as a 1st embodiment, and the statement is omitted about overlapping explanation.
[0072]A 1st embodiment explained a full flattery state where a subject under conveyance and relative physical relationship with the robot end point position P became almost the same as those relative physical relationship at the time of teaching work. On the other hand, by a 2nd embodiment, when it is not in a full flattery state, it explains that a robot device grasps a subject.
[0073]Here, with a flattery state, it is defined as the state where relative position relation was kept constant. For example, in a case where a subject is exercising by speed V_0, the robot end point position P is in a state where it is exercising by speed V_0. Next, two, a "full flattery state" and an "imperfect flattery state", are defined as a flattery state.
[0074]A state which is carrying out fixed time continuation while relative physical relationship of the robot end point position P and a subject has been constant value P_O, i.e., the state of being the same as those relative physical relationship at the time of teaching work, is called "full flattery state." A state which is changing fixed time continuation into an "imperfect flattery state" while relative physical relationship of the robot end point position P and a subject has been constant value P'_0 (!=P_O), That is,

although there is no change of a position relative between the robot end point position P and a subject, the state of differing from relative physical relationship at the time of teaching work is said. About these two states, a state of speed of a picture error, the robot end point position P, and the robot end point position P and acceleration of the robot end point position P is shown in Table 1.
[0075]
[Table 1]

運動	完全追従状態				不完全追従状態			
	画像	手先			画像	手先		
	誤差	位置	速度	加速度	誤差	位置	速度	加速度
静止	微小	一定	0	0	一定	一定	0	0
等速直線	微小	－	一定	0	一定	－	一定	0
等速円	微小	－	一定	一定	一定	－	一定	一定
等加速度直線	微小	－	－	一定	一定	－	－	一定

[0076]"In the state of full flattery", relative physical relationship of the robot end point position P and a subject is P_O, and, moreover, the robot end point position P is moved at the same speed as a subject. For this reason, the approaching operation can perform grip operations by moving approach move P_O, maintaining the following movement V.
[0077]On the other hand, the robot end point position P is moved at the same speed as a subject also "in the state of imperfect flattery." However, relative physical relationship P'_0 of the robot end point position P and a subject differs from physical relationship P_O at the time of teaching work. For example, as shown in drawing 12 (A), the initial picture of the subject 11 at the time of a flattery start is not in agreement with a target image. In order to make it be in a flattery state early at this time, the speed of the robot end point position Ps is large as shown in drawing 13. As shown in drawing 12 (B), the predetermined gap will be maintained the picture of the subject 11 of a flattery state to the target image. The speed of the robot end point position Ps at this time is V_{actual} (t_l) as shown in drawing 13.
[0078]Then, if relative-position-relation P'_0 can be taught, as shown in drawing 12 (C), the completely same effect as a "full flattery state" can be acquired. Physical relationship P'_0 in an "imperfect flattery state" has **** which changes by change of the motion velocity of a subject, change of the gain of a visual servo, etc., and re-instruction is required for it at every time. According to this embodiment, re-teaching work is performed so that it can respond to an "imperfect flattery state."
[0079](Re-teaching work and grip operations) In re-teaching work, first, a visual servo is used and flattery of a subject is performed. And the robot controller 5 extracts image-characteristic-quantity F'i of a subject at this time, and memorizes the coordinates of each image-characteristic-quantity F'i. The extracting processing of image-characteristic-quantity F'i is the same as processing of step ST6 shown in drawing 3.
[0080]Next processings from step ST1 to step ST3 shown in drawing 3 are performed, and the gripper 3 is moved to arbitrary positions (robot end point position Ps). Further, the robot controller 5 performs a visual servo using image-characteristic-quantity Fi', and makes the position of the gripper 3 which reached the flattery state robot end point position P's. And the robot controller 5 computes positional attitude transformation-

matrix P'_O ($=P'_S{}^{-1}Pd$) in a flattery state, and memorizes this positional attitude transformation-matrix P'_O.

[0081]In grip operations, processings from step ST11 to step ST18 shown in drawing 7 are performed like a 1st embodiment. What is necessary is to replace with the image characteristic quantity Fi and positional attitude conversion P_O which were calculated by a 1st embodiment, and just to use image-characteristic-quantity F'i and positional attitude conversion business sequence P'_O at this time.

[0082]As mentioned above, according to the robot device concerning a 2nd embodiment, even if the robot end point position P does not follow the subject 11 thoroughly, the subject 11 can be grasped only by performing easy teaching work mentioned above without carrying out complicated adjustment.

[0083](A 3rd embodiment) According to 1st and 2nd embodiments, although the case of stillness movement and linear uniform motion was shown as an example, if this invention is used, it is expandable to a linear motion of acceleration or uniform circular motion. And processings from step ST11 to step ST17 shown in drawing 7 are performed like [these grip operations] a 1st embodiment.

[0084]In the case of a linear motion of acceleration, specifically the robot controller 5, In time t_1 to which the error vector E (t) became small enough, Judge with the robot end point position P having been relatively controlled by the position of P_O or P'_O to the subject 11, and V_{actual} (t_1) in this time t_1, Velocity component $V_{estimate}$ (t) generated from hand acceleration acc_{actual} (t_1), The speed commanding value which piled up the speed commanding value generated from P_O or P'_O is generated, the subject 11 is approached from the robot end point position P in time t_1 (t_1), and the subject 11 is grasped by the gripper 3.

[0085]That is, the robot controller 5 is controlled to move the gripper 3 by P_O from the robot end point position Ps when it changes into a flattery state to be shown in drawing 14. The robot controller 5 computes P_a according to the following formulas noting that it takes time T'_O to carry out P_O part relative displacement at this time.

[0086]

[Equation 6]

$$P_a = P(t_1) + P_0 + V_{actual}(t_1) \cdot T_0' + \int_0^{T_0'} V_{estimate}(t)\,dt$$

[0087]Although the case where a subject was grasped was mentioned as the example and the embodiment mentioned above explained it, this invention is not limited to this. For example, even if it is a case where attachment of parts, etc. are carried out to the subject 11, it is applicable similarly.

[0088]

[Effect of the Invention]According to a robot device concerning this invention, and a method for controlling the same, the operator should just perform the following two things as teaching work. A gripping mechanism is moved to the 1st end point position, and a subject is made 1st to grasp here. From a gripping mechanism, a subject is made to release and a gripping mechanism is moved [2nd] to the 2nd end point position into an imaging range. The coordinates of the characteristic quantity of the subject in the 1st and 2nd end point positions and the 2nd end point position which are memorized at this time

are used in order to follow a subject and to grasp this. That is, an operator only performs easy teaching work and can make the subject under movement to a robot device grasp.

TECHNICAL FIELD

[Field of the Invention]This invention relates to a robot device and a method for controlling the same, and relates to a robot device which grasps the object under movement especially, and a method for controlling the same.

PRIOR ART

[Description of the Prior Art]When working to a subject using a robot (for example, objective grasping), information, including the position of a subject, a posture, etc., is acquired by a sensor, and many examples which work based on the sensor information are put in practical use. As such an equipment configuration, it divides roughly and, generally there are the following two methods.
[0003]For example, there are some which detect the position of a subject and a posture from the picture acquired by picturizing with the camera which had the subject which has a conveyor top conveyed fixed, and transmit the information to a robot as indicated to JP,8-63214,A. This robot is working grasping etc. from the position information on a subject.
[0004]Sensors, such as a camera, are attached to the hand of a robot, the target positional attitude is detected from the picture from a camera as mentioned above, and there are some which follow the subject which moves based on the information, and work grasping etc.

EFFECT OF THE INVENTION

[Effect of the Invention]According to a robot device concerning this invention, and a method for controlling the same, the operator should just perform the following two things as teaching work. A gripping mechanism is moved to the 1st end point position, and a subject is made 1st to grasp here. From a gripping mechanism, a subject is made to release and a gripping mechanism is moved [2nd] to the 2nd end point position into an imaging range. The coordinates of the characteristic quantity of the subject in the 1st and 2nd end point positions and the 2nd end point position which are memorized at this time are used in order to follow a subject and to grasp this. That is, an operator only performs easy teaching work and can make the subject under movement to a robot device grasp.

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]However, when realizing the work of grasping of a subject, etc. using the camera installed apart from the robot like the former, the work

which asks for the installed position of a robot and a camera correctly beforehand is needed. It is necessary to perform the camera calibration which computes a focal distance, a lens strain coefficient, etc. of the camera beforehand.
[0006]In addition, in the example in JP,8-63214,A etc., it is necessary to install so that the optic axis of a camera may generally become vertical still more nearly parallel to the transportation direction of a conveyor at a conveyor flat surface in the x axis or the y-axis in a screen. Since the subject is running by the band conveyor etc., in addition to the position attitude information of the subject detected by the picture from a camera, another means (for example, encoder of a conveyor) needs to detect the speed information of a conveyor, etc., and it is necessary to generate the command value to a robot based on both information. The orbit at the time of a robot grasping a subject from the installation position information of a camera and a robot, the position information on a subject, and the speed information of a conveyor must be generated. Therefore, there are problems, like the procedure for teaching work and trajectory generation becomes very complicated.
[0007]It can say such a problem that the same may be said of the example of the latter which installed the camera to the hand of the robot in conventional technology. That is, when a subject is grasped by the gripper etc. which were attached to the hand of a robot based on the position attitude information of the subject detected from the picture from a camera, What is called a hand eye calibration that needs to change the position attitude information of the subject acquired from the camera into the position attitude information seen from the standard coordinates of the robot, and searches for the physical relationship of a robot hand and a camera precisely beforehand is needed. When sensors, such as a camera, are especially installed in a robot hand, a camera position relation with a robot hand frequently changes with the malfunctions under work, etc., and it is necessary to do calibration work again in that case. When the subject is moving like the former example, since the position attitude information of the subject seen from the robot normal coordinate changes every moment, it becomes very complicated [the trajectory generation for grasping].
[0008]In the former, even if the method of the former and the latter changes neither a component (the installation condition of a conveyor, a bearer rate, or the installed position relation between a camera and a robot), nor the shape of a subject which should be grasped, Whenever the robot and sensor to be used changed, the above-mentioned highly precise calibration and complicated teaching work needed to be performed.
[0009]This invention is proposed in order to cancel the problem mentioned above, and it is a thing.
The purpose is to provide a robot device which can save the time and effort which performs work and a calibration, and can make predetermined work do on a subject easily, and a method for controlling the same.

MEANS

[Means for Solving the Problem]A holding means from which the invention according to claim 1 has a gripping mechanism which grasps a subject and which said gripping mechanism comprised movable, An imaging means which is fixed movable with a gripping mechanism of said holding means, and picturizes a subject, A feature amount

extracting means which extracts coordinates of one or more characteristic quantity from a picture of a subject which said imaging means picturized, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when moving said gripping mechanism within limits which can make said subject able to open wide and in which said imaging means can picturize a subject is memorized as the 2nd end point position, A memory measure which memorizes coordinates of each characteristic quantity of said subject which said imaging means picturized in said 2nd end point position, and said feature amount extracting means extracted, A calculating means which computes a move procession for moving from said 2nd end point position to said end point position of 1, Coordinates of each characteristic quantity of a subject under movement extracted by said feature amount extracting means by moving said holding means so that it may be in agreement with coordinates of each characteristic quantity memorized by said memory measure. When a follow-up control means which carries out control which said gripping mechanism is made to follow to a subject under said movement, and a subject while said gripping mechanism is exercising are followed, Based on a move procession which said calculating means computed, said gripping mechanism is brought close to a subject under said movement, and it has a grasping control means which controls said holding means to make said subject grasp.
[0011]The robot device according to claim 1 grasps a subject which exercises relatively to the robot device concerned. Therefore, a case where said robot device exercises and said subject is being fixed, when said robot device and said subject are exercising at a speed different, respectively, and not only when said robot device is fixed and said subject exercises, but when, it can apply. Although said subject may be carrying out the acceleration straight-line motion of linear uniform motion, the uniform circular motion, etc. relatively to said robot device, it may be standing it still relatively.
[0012]First, the operator needs to perform the following two things as teaching work. A gripping mechanism is moved to the 1st end point position, and a subject is made 1st to grasp here. A subject is made to release from a gripping mechanism and an imaging means moves [2nd] a gripping mechanism within limits which can picturize a subject to the 2nd end point position. Such teaching work is performed and a memory measure is made to memorize the 1st and 2nd end point positions. A memory measure is made to also memorize coordinates of one or more characteristic quantity extracted from a picture which an imaging means picturized in the 2nd end point position. An imaging means serves as a sensor of a gripping mechanism, and it is being fixed so that it may move with a holding means. A move procession for moving from the 2nd end point position to the 1st end point position is computed.
[0013]If such teaching work is completed, grip operations which grasp a subject under movement can be performed. A gripping mechanism is moved so that coordinates of each characteristic quantity of a subject under movement may be in agreement with coordinates of each characteristic quantity memorized by said memory measure. That is, what is called a visual servo is performed so that a subject while a gripping mechanism is exercising may be followed. Relative physical relationship of a subject at this time and a gripping mechanism is the same as a subject at the time of teaching work, and that relative of a gripping mechanism. When a subject while said gripping mechanism is exercising is followed, based on the 1st move procession that said calculating means

computed, said gripping mechanism is brought close to a subject under said movement, and said subject is made to grasp.
[0014]It is desirable for a gripping mechanism to follow a subject under movement thoroughly in a case where a visual servo is being performed. However, a gripping mechanism may follow, separating prescribed distance to a subject under movement. In such a case, it is preferred that re-teaching work which is indicated to claim 2 is performed. While said gripping mechanism separates said memory measure prescribed distance to a subject under said movement by said follow-up control means, when it follows, specifically, Coordinates of each characteristic quantity of said subject which said feature amount extracting means extracted are newly memorized, What is necessary is just to memorize a position of said gripping mechanism when said follow-up control means makes said gripping mechanism follow a subject thoroughly from said 2nd end point position using coordinates of each newly memorized characteristic quantity as the 2nd new end point position.
[0015]The invention according to claim 3 is the control method of a robot device which grasps a subject by a gripping mechanism constituted movable, A position of a gripping mechanism at a time of making said gripping mechanism grasp said subject is memorized as the 1st end point position, A position of said gripping mechanism when making said subject open wide and moving said gripping mechanism within limits which can picturize a subject is memorized as the 2nd end point position, In said 2nd end point position, picturize said subject, and coordinates of one or more characteristic quantity are extracted from a picture of said picturized subject, In the state where memorized coordinates of each of said extracted characteristic quantity, computed a move procession for moving from said 2nd end point position to said end point position of 1, and it was fixed movable with said gripping mechanism. Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized movement, Coordinates of each characteristic quantity of a subject under said extracted movement by moving said gripping mechanism so that it may be in agreement with coordinates of each of said characteristic quantity memorized. When said gripping mechanism is made to follow a subject under said movement and a subject while said gripping mechanism is exercising is followed, based on said computed move procession, said gripping mechanism is brought close to a subject under said movement, Said gripping mechanism is made to grasp said subject.
[0016]This invention is a method for controlling a robot device indicated to claim 1, and the operator should just perform two things mentioned above as teaching work. That is, only by an operator performing two easy teaching work, a gripping mechanism can be made to be able to follow a subject which is exercising and the subject can be grasped.
[0017]It is desirable for a gripping mechanism to follow a subject under movement thoroughly in a case where a visual servo is being performed. However, a gripping mechanism may follow, separating prescribed distance to a subject under movement. In such a case, it is preferred that re-teaching work which is indicated to claim 4 is performed. While said gripping mechanism specifically separates prescribed distance to a subject under said movement, when it makes said gripping mechanism follow a subject under said movement, and it follows, it is in a state fixed movable with said gripping mechanism, Picturize a subject under movement and coordinates of one or more characteristic quantity are extracted from a picture of a subject under said picturized

movement, Newly memorize coordinates of each characteristic quantity of said said extracted subject, and coordinates of each of said newly memorized characteristic quantity are used, What is necessary is just to memorize a position of said gripping mechanism as the 2nd new end point position, when said gripping mechanism is moved so that said gripping mechanism may follow a subject thoroughly from said 2nd end point position, and followed thoroughly.

[0018]

[Embodiment of the Invention]Hereafter, it explains in detail, referring to drawings for an embodiment of the invention.

[0019](A 1st embodiment) As shown in drawing 1, the robot device concerning this embodiment grasps the subject 11 currently conveyed by conveyor 10 in the state where it was fixed. This invention is not limited to such an embodiment, and if the subject 11 is exercising relatively to a robot device, it is applicable. That is, they may be a case where a robot device exercises and the subject 11 is standing it still, and a case where it is exercising at the speed from which a robot device and the subject 11 differ. 2nd and 3rd embodiments are also the same.

[0020]A robot device is provided with the following.

CCD camera 1 which picturizes the subject 11.

The sensor controller 2 which extracts characteristic quantity from the picture which CCD camera 1 picturized.

The gripper 3 which grasps the subject 11.

The robot controller 5 which performs the robot arm 4 which moves the gripper 3 in the direction of a three dimension, coordinate conversion, trajectory generation, etc., has a servo circuit, amplifier, etc. which are not illustrated, and controls operation of the gripper 3 or the robot arm 4.

[0021]CCD camera 1 has adhered near the gripper 3 which is a tip of the robot arm 4. The robot controller 5 computes error vector E (t) and the speed commanding value vector V (t) based on the image characteristic quantity Fi obtained with the sensor controller 2, and controls movement of the robot arm 4, and grasping of the subject 11 by the gripper 3 according to these values. The conveyor 10 conveys the subject 11 at a fixed speed.

[0022]Before the robot device of such composition actually grasps the subject 11 currently conveyed, teaching work for grasping the subject 11 is performed.

[0023](Teaching work) First, an operator makes a robot device grasp the subject 11, and teaches the robot end point position P. The position which should be grasped may be restricted by the shape of gripping mechanisms, such as the gripper 3, and the subject 11. The position which should be grasped for next processing (for example, attach other parts to the subject 11, or supply to a parts box) may be specified beforehand.

[0024]Here, as shown, for example in drawing 2, the subject 11 was formed in 7 prismatic forms, and is provided with the seven sides 111-117. Six attachment holes (for example, tapped hole) for attaching the parts which are not illustrated are formed in the upper surface 118 of the subject 11. Such an attachment hole is not formed in the undersurface 119 of the subject 11. As for the portion by which the subject 11 is grasped, it is preferred that they are the side 111,115 in which it faces among seven sides in consideration of stability when grasped, or the side 113,116. Although the subject 11 of

the above-mentioned shape was used in this embodiment, this invention may not be limited to this shape and the subjects 11 may be other shape. And teaching work is specifically performed according to processing of step ST1 to step ST6 shown in drawing 3.

[0025]In step ST1, an operator shifts to step ST2, as the gripper 3 grasps the side 111,115 or the side 113,116 of the subject 11 using the teaching pendant etc. which are not illustrated.

[0026]In step ST2, as shown in drawing 4, the gripper 3 is in the state which grasped the subject 11, and the robot controller 5 memorizes, the position, i.e., robot end point position Pd, of the gripper 3 in robot standard coordinates, and shifts to step ST3. The "position" said here is expressed with the parameter of 6 flexibility including a posture. The parameter of 6 flexibility including a posture is called "position" like the following.

[0027]In step ST3, the robot controller 5 makes the subject 11 which the gripper 3 grasped release, and moves the gripper 3 to arbitrary positions, and shifts to step ST4.

[0028]It requires that the position which the gripper 3 moves is in the visual field range of CCD camera 1. That is, it is a position where the characteristic quantity of the subject 11 is extracted from the picture picturized with CCD camera 1. It is a position where characteristic quantity which should be extracted, such as a position to which the subject 11 is not settled in the view of CCD camera 1, and a position in which CCD camera 1 picturizes the subject 11 from just beside, is specifically suitably obtained from a picture.

[0029]In step ST4, the robot controller 5 memorizes, as shown in drawing 5, the position Ps, i.e., the robot end point position, of the gripper 3 in the present robot standard coordinates, and it shifts to step ST5.

[0030]Here, the following formulas will be realized if the positional attitude transformation matrix for changing into Pd from the robot end point position Ps is made into P_O.

[0031]Ps-P_O=PdthereforeP$_O$=Ps^{-1} and the Pd robot controller 5 compute positional attitude transformation-matrix P_O at this time, and memorizes this. The robot controller 5 may compute positional attitude transformation-matrix P_O in the case of the grip operations mentioned later.

[0032]In step ST5, CCD camera 1 picturizes the subject 11 in the robot end point position Ps, and supplies this picture to the sensor controller 2. The sensor controller 2 extracts image characteristic quantity based on the picture from CCD camera 1, and shifts to step ST6. Here, CCD camera 1 acquires the picture of the subject 11 as shown, for example in drawing 6.

[0033]In step ST6, six attachment holes processed into the upper surface 118 of the subject 11 are extracted as the image characteristic quantity Fi (i= 1-6), the center position of each image characteristic quantity Fi carries out coordinate value (Xi, Yi) memory, and the sensor controller 2 ends processing of teaching work.

[0034]What is necessary is just to use publicly known techniques, such as binarization image processing and edge processing, as an instrumentation method of the center position of the attachment hole in a picture. Although it attached here and the center position of the hole was made into the image characteristic quantity Fi, the area center of gravity of the isolated field of a line segment corner point, a corner, and a binarization picture, etc. may use other image characteristic quantity. An operator may give a definition artificially by the input means in which neither a mouse nor a keyboard

illustrates the image characteristic quantity Fi at the time of instruction.
[0035](Grip operations) A robot device grasps the subject 11 under conveyance using the coordinates of the image characteristic quantity Fi memorized on the occasion of the work, and the robot end point positions Pd and Ps, after teaching work is completed. In these grip operations, processings from step ST11 to step ST18 shown in drawing 7 are performed.
[0036]In step ST11, as shown in drawing 8, CCD camera 1 picturizes a transportation area [of the subject 11] 10, i.e., conveyor, top, and shifts to step ST12.
[0037]In step ST12, the sensor controller 2 judges whether the subject 11 was detected. In order to detect the subject 11 and to extract characteristic quantity from the picture, it is required for the subject 11 whole to enter within the limits of the view of CCD camera 1. Here, the luminosity of a picture is used for detection of the subject 11. For example, when the subject 11 is upstream of the conveyor 10 and there is into the visual field range of CCD camera 1, the luminosity of the picture acquired with CCD camera 1 hardly changes. [no] On the other hand, if the subject 11 is conveyed by conveyor and it enters in the visual field range of CCD camera 1, the luminosity will change. Then, it judges with the sensor controller 2 providing the window which is not illustrated in the suitable position in a picture, and the subject 11 being in a visual field range, when the luminosity in the window is beyond a predetermined threshold, and when luminosity is less than a predetermined threshold, it judges with there being nothing within the limits of the view. And when the sensor controller 2 detects the subject 11, it shifts to step ST13, and when it does not detect, it returns to step ST11.
[0038]image-characteristic-quantity fi(t) (i=1 in the time T from a picture when CCD camera 1 picturized the sensor controller 2 in step ST13, and 2 ...) -- it extracts and shifts to step ST14. Here, drawing 9 is a figure showing the picture picturized at the time of execution of grip operations. It is necessary to extract the image characteristic quantity fi (t) from the picture picturized at the time t at the time of grip operations. However, there is a thing which should extract essentially by a certain cause and for which the image characteristic quantity f3 (t) is extracted for example, it does not come out. Then, the characteristic quantity f1 (t) - f7 (t) need to perform corresponding point searching which asks for any of F1 - F6 which show drawing 6 are supported.
[0039]This corresponding point searching can be performed with what is called checking methods, such as dynamic programming, a largest faction method, etc. which various methods are proposed, for example, are indicated to "robot vision" (Masahiko Yanaida work, Shokodo, 1990). If F1 - the thing corresponding to F6 are obtained out of f1-f7, the following image characteristic quantity can once be calculated easily.
[0040]What is necessary is just to specifically extract the image characteristic quantity fi (t+deltat) in the next time (t+deltat) of the time t near the image characteristic quantity fi in the inside of a previous picture (t), if cycle time of the repetition processings from step ST13 to step ST16 is set to deltat. Thereby, the stability of characteristic quantity extraction can ease increase and the burden of computation.
[0041]In step ST14, the sensor controller 2, It judges whether the error vector E (t) in the time t is small enough, or the judging standard of ||E(t) ||<epsilon is specifically met, when small enough, it shifts to step ST17, and when not small enough, it shifts to step ST15.
[0042]Here, the error vector E (t) is searched for based on the image characteristic

quantity fi (t) extracted from the picture of present CCD camera 1, and the image characteristic quantity Fi memorized by step ST6 mentioned above.
[0043]In this invention, literature B.Espiau et al., A New Approach to Visual Servoing in Robotics, IEEE Trans.Robotics and Automation, 8 (3), and 313-326-1992, Literature F.Bensalha et al. and Real Time Visual Tracking using the Generalized Likelihood Ratio Test,Int.Conf.Automation,Robotics and. Based on Computer Vision and the technique indicated to 1379-1383-1994, the error vector E (t) and the speed commanding value vector V (t) mentioned later are computed.
[0044]It asks for characteristic quantity deviation vector e (t) by the following formulas (1) using image-characteristic-quantity fi (t) = (Xi (t), Yi (t)) obtained from the picture picturized at image-characteristic-quantity Fi= at the time of instruction (Xi, Yi), and the time t.
[0045]
[Equation 1]

$$e(t)=\begin{pmatrix} x_1(t)-x_1 \\ y_1(t)-y_1 \\ x_2(t)-x_2 \\ y_2(t)-y_2 \\ \cdot \\ \cdot \\ x_N(t)-x_N \\ y_N(t)-y_N \end{pmatrix} \quad \cdots (1)$$

[0046](xi, yi) and (xi(t), and yi (t)) are expressed with a pixel value (Xi, Yi), and change (Xi(t) and Yi (t)) into the value in a camera coordinate system, respectively. N expresses the number of image characteristic quantity.
[0047]The error vector E (t) is expressed with a formula (2) using above-mentioned characteristic quantity deviation vector e (t).
[0048]
[Equation 2]

$$E(t)=L^{T+}e(t) \quad \cdots (2)$$

[0049]Here, L^{T+} is a false inverse matrix of picture Jacobian L^T calculated from the image characteristic quantity F and F (t).
[0050]It judges with the sensor controller 2 having followed the subject 11 which exercises, when the judging standard of ||E(t) ||<epsilon was met. epsilon is scalar quantity beforehand given by an operator. Or as long as it expresses E=(E1 E2 E3 E4 E5 E6) ^{T}, the judging standard shown in a formula (3) may be used.
[0051]
[Equation 3]

$$\max_i E_i < \varepsilon \quad \cdots (3)$$

[0052]In step ST15, the robot controller 5 computes the speed commanding value vector V (t), and shifts to step ST16. The speed commanding value vector V contains the advancing-side-by-side speed (t_x, t_y, t_z) and revolving speed (omega$_x$, omega$_y$, omega$_z$) of the robot end point position P, It is expressed V=($t_x t_y t_z$omega$_x$omega$_y$omega$_z$) ^{T}. And the

speed commanding value vector V (t+deltat) in time (t+deltat) is searched for from a formula (4).
[0053]
[Equation 4]

$$V(t+\Delta t)=-\lambda L^{T+}e(t)-\widehat{T^{o}(t)} \quad \cdot\cdot\cdot (4)$$

[0054]lambda is a speed gain. The rightmost paragraph of the right-hand side of a formula (4) is a point estimate of the motion velocity of the subject 11, and is searched for from a formula (5).
[0055]
[Equation 5]

$$\widehat{T^{o}(t)}=\frac{E(t)-E(t-\Delta t)}{\Delta t}-V(t) \quad \cdot\cdot\cdot (5)$$

[0056]The robot controller 5 computes error vector E (t) and the speed commanding value vector V (t) as mentioned above.
[0057]In step ST16, the robot controller 5 generates trajectory generation, and joint angular velocity and angular acceleration based on the computed speed commanding value vector V (t), controls the robot arm 4 according to these, and returns to step ST13.
[0058]In step ST17 when E (t) judges with it being small enough by step ST14, the robot controller 5 judges with the gripper 3 having followed the subject 11, and starts approach to the subject 11. In the following explanation, it is called visual servo by processing the flow chart shown in drawing 7 to make the gripper 3 follow a subject.
[0059]Here, if time which shifted to step ST14 is made into time t_1, as shown, for example in drawing 10, as for a speed commanding value vector, a position vector of V_{actual} (t_1) and a robot end point position will be set to P (t_1).
[0060]In time t_1, since the robot end point position P follows the subject 11, its speed commanding value vector V_{actual} at that time (t_1) is equal to a velocity vector of the subject 11. Therefore, the robot controller 5 generates a speed pattern on which a speed pattern for moving by P_O from the end point position P (t_1) was made to superimpose speed commanding value vector V_{actual} (t_1) mentioned above. P_O is the positional attitude transformation matrix shown by teaching work. A speed pattern for moving by P_O is computable with the conventional techniques, such as a trapezoid speed pattern, for example.
[0061]The robot controller 5 computes P_a according to the following formulas noting that it takes time T_O to carry out P_O part relative displacement.
[0062]
$P_a=P(t_1)+P_O+V_{actual}(t_1)$, T_O, and the robot controller 5 control the robot arm 4 based on computed P_a. Thereby, as shown in drawing 11, a robot hand (gripper 3) can be moved to position P_a which should grasp the subject 11 from the end point position P (t_1). After such approach is completed, it shifts to step ST18.
[0063]In step ST18, the robot controller 5 grasps the subject 11 by the gripper 3, and ends processing.
[0064]As mentioned above, the robot device can memorize the robot end point positions Ps and Pd at the time of teaching work, and can follow the subject 11 under conveyance by a visual servo, and can perform grip operations of the subject 11 using the robot end point positions Ps and Pd. Thereby, the robot device can grasp the subject 11 under

conveyance easily, without [without it is restrained by attitude position of the subject 11 under conveyance, and] stopping the conveyor 10.
[0065]Since work which searches for beforehand physical relationship the installed position, CCD camera 1, the gripper 3, and between subject 11 is unnecessary, the above-mentioned robot device, For example, even if it is a case where installation requirements of CCD camera 1 change, the subject 11 under conveyance can be grasped only by simple teaching work which was mentioned above. Even if it is a case where the subjects 11 which should be grasped differ when it is going to realize the same work by a different robot device, CCD camera 1, and the gripper 3, only simple teaching work is similarly.
[0066]Thereby, the operator can reduce load in the conventional teaching work and programming substantially. Even if change arises in CCD camera 1, the gripper 3, and the subject 11, it can respond flexibly.
[0067]In an embodiment mentioned above, although it mentioned as an example grasping the subject 11 currently conveyed by conveyor 10 and it was explained, a robot device can be made the same, also when grasping the stationary subject 11.Teaching work is the same as explanation mentioned above.
[0068]In grip operations, in step ST14 shown in drawing 7, when the error vector E (t) becomes small enough, the speed commanding value vector V (t) becomes zero, and speed V_{actual} (t_1) of a actual robot end point position becomes zero similarly.
[0069]Therefore, in step ST17, the robot controller 5 can grasp the subject 11 only using change part P_O of the present robot end point position P (t_1) and a position at the time of instruction. That is, position P_a which should be grasped is calculated by the following formulas.
[0070]$P_a=P(t_1)+P_O$ and the robot controller 5 can control the robot arm 4 based on computed P_a, and can grasp the subject 11 stationary by the gripper 3.
[0071](A 2nd embodiment) Below, a 2nd embodiment of this invention is described. The same numerals are given to the same part as a 1st embodiment, and the statement is omitted about overlapping explanation.
[0072]A 1st embodiment explained a full flattery state where a subject under conveyance and relative physical relationship with the robot end point position P became almost the same as those relative physical relationship at the time of teaching work. On the other hand, by a 2nd embodiment, when it is not in a full flattery state, it explains that a robot device grasps a subject.
[0073]Here, with a flattery state, it is defined as the state where relative position relation was kept constant. For example, in a case where a subject is exercising by speed V_0, the robot end point position P is in a state where it is exercising by speed V_0. Next, two, a "full flattery state" and an "imperfect flattery state", are defined as a flattery state.
[0074]A state which is carrying out fixed time continuation while relative physical relationship of the robot end point position P and a subject has been constant value P_O, i.e., the state of being the same as those relative physical relationship at the time of teaching work, is called "full flattery state." A state which is changing fixed time continuation into an "imperfect flattery state" while relative physical relationship of the robot end point position P and a subject has been constant value P'_0 $(!=P_O)$, That is, although there is no change of a position relative between the robot end point position P and a subject, the state of differing from relative physical relationship at the time of teaching work is said. About these two states, a state of speed of a picture error, the robot

end point position P, and the robot end point position P and acceleration of the robot end point position P is shown in Table 1.
[0075]
[Table 1]

運 動	完全追従状態				不完全追従状態			
	画像	手先			画像	手先		
	誤差	位置	速度	加速度	誤差	位置	速度	加速度
静 止	微小	一定	0	0	一定	一定	0	0
等速直線	微小	−	一定	0	一定	−	一定	0
等速円	微小	−	一定	一定	一定	−	一定	一定
等加速度直線	微小	−	−	一定	一定	−	−	一定

[0076]"In the state of full flattery", relative physical relationship of the robot end point position P and a subject is P_O, and, moreover, the robot end point position P is moved at the same speed as a subject. For this reason, the approaching operation can perform grip operations by moving approach move P_O, maintaining the following movement V.
[0077]On the other hand, the robot end point position P is moved at the same speed as a subject also "in the state of imperfect flattery." However, relative physical relationship P'_0 of the robot end point position P and a subject differs from physical relationship P_O at the time of teaching work. For example, as shown in drawing 12 (A), the initial picture of the subject 11 at the time of a flattery start is not in agreement with a target image. In order to make it be in a flattery state early at this time, the speed of the robot end point position Ps is large as shown in drawing 13. As shown in drawing 12 (B), the predetermined gap will be maintained the picture of the subject 11 of a flattery state to the target image. The speed of the robot end point position Ps at this time is V_{actual} (t_1) as shown in drawing 13.
[0078]Then, if relative-position-relation P'_0 can be taught, as shown in drawing 12 (C), the completely same effect as a "full flattery state" can be acquired. Physical relationship P'_0 in an "imperfect flattery state" has **** which changes by change of the motion velocity of a subject, change of the gain of a visual servo, etc., and re-instruction is required for it at every time. According to this embodiment, re-teaching work is performed so that it can respond to an "imperfect flattery state."
[0079](Re-teaching work and grip operations) In re-teaching work, first, a visual servo is used and flattery of a subject is performed. And the robot controller 5 extracts image-characteristic-quantity F'i of a subject at this time, and memorizes the coordinates of each image-characteristic-quantity F'i. The extracting processing of image-characteristic-quantity F'i is the same as processing of step ST6 shown in drawing 3.
[0080]Next processings from step ST1 to step ST3 shown in drawing 3 are performed, and the gripper 3 is moved to arbitrary positions (robot end point position Ps). Further, the robot controller 5 performs a visual servo using image-characteristic-quantity Fi', and makes the position of the gripper 3 which reached the flattery state robot end point position P's. And the robot controller 5 computes positional attitude transformation-matrix P'_O ($=P'^{-1}_S Pd$) in a flattery state, and memorizes this positional attitude transformation-matrix P'_O.
[0081]In grip operations, processings from step ST11 to step ST18 shown in drawing 7

are performed like a 1st embodiment. What is necessary is to replace with the image characteristic quantity Fi and positional attitude conversion P_O which were calculated by a 1st embodiment, and just to use image-characteristic-quantity F'i and positional attitude conversion business sequence P'_O at this time.

[0082]As mentioned above, according to the robot device concerning a 2nd embodiment, even if the robot end point position P does not follow the subject 11 thoroughly, the subject 11 can be grasped only by performing easy teaching work mentioned above without carrying out complicated adjustment.

[0083](A 3rd embodiment) According to 1st and 2nd embodiments, although the case of stillness movement and linear uniform motion was shown as an example, if this invention is used, it is expandable to a linear motion of acceleration or uniform circular motion. And processings from step ST11 to step ST17 shown in drawing 7 are performed like [these grip operations] a 1st embodiment.

[0084]In the case of a linear motion of acceleration, specifically the robot controller 5, In time t_1 to which the error vector E (t) became small enough, Judge with the robot end point position P having been relatively controlled by the position of P_O or P'_O to the subject 11, and V_{actual} (t_1) in this time t_1, Velocity component $V_{estimate}$ (t) generated from hand acceleration acc_{actual} (t_1), The speed commanding value which piled up the speed commanding value generated from P_O or P'_O is generated, the subject 11 is approached from the robot end point position P in time t_1 (t_1), and the subject 11 is grasped by the gripper 3.

[0085]That is, the robot controller 5 is controlled to move the gripper 3 by P_O from the robot end point position Ps when it changes into a flattery state to be shown in drawing 14. The robot controller 5 computes P_a according to the following formulas noting that it takes time T'_O to carry out P_O part relative displacement at this time.

[0086]

[Equation 6]

$$P_a = P(t_1) + P_0 + V_{actual}(t_1) \cdot T_0' + \int_0^{T_0'} V_{estimate}(t)dt$$

[0087]Although the case where a subject was grasped was mentioned as the example and the embodiment mentioned above explained it, this invention is not limited to this. For example, even if it is a case where attachment of parts, etc. are carried out to the subject 11, it is applicable similarly.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1]It is a figure showing the composition of the robot device concerning a 1st embodiment of this invention.

[Drawing 2]It is an appearance perspective view of the subject grasped by a robot device.

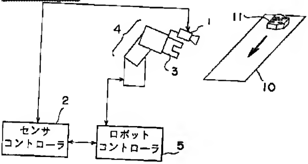
[Drawing 3]It is a flow chart which shows the contents of processing in the teaching work of a robot device.

[Drawing 4]In teaching work, it is a figure showing the rough composition which shows robot end point position Pd in the state where the subject was grasped.

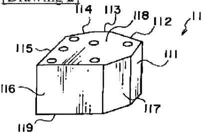
[Drawing 5]In teaching work, it is a figure showing the rough composition which shows the robot end point position Ps when a subject is released.
[Drawing 6]It is a figure showing the image pick of the camera in teaching work.
[Drawing 7]It is a flow chart which shows the contents of processing in the grip operations of a robot device.
[Drawing 8]In grip operations, it is a figure for explaining that the camera is picturizing the conveyor top which conveys a subject.
[Drawing 9]It is a figure showing the image pick of the camera in grip operations.
[Drawing 10]It is a figure for explaining the robot end point position P in time t_1 (t_1), and speed commanding value vector V_{actual} (t_1).
[Drawing 11]It is a figure explaining a state when grasping a subject.
[Drawing 12]It is a figure showing the picture of an initial state, a flattery state, and the subject at the time of re-instruction in the robot device concerning a 2nd embodiment.
[Drawing 13]It is a figure explaining the speed commanding value vector V (t) of the robot end point position P.
[Drawing 14]It is a figure explaining the state where the subject which the robot device concerning a 3rd embodiment of this invention is conveying was grasped.
[Description of Notations]
1 Camera
2 Sensor controller
3 Gripper
4 Robot arm
5 Robot controller

DRAWINGS

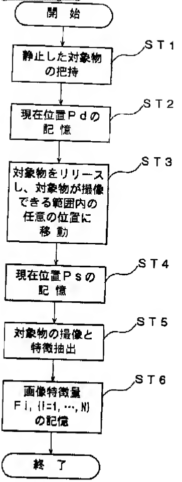
[Drawing 1]



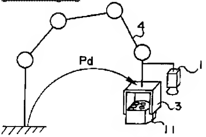
[Drawing 2]



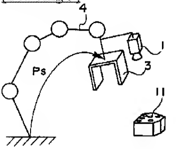
[Drawing 3]



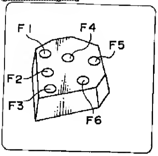
[Drawing 4]



[Drawing 5]



[Drawing 6]



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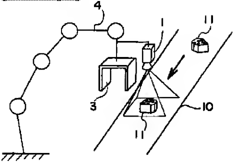
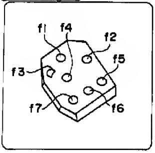
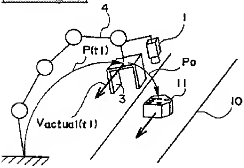


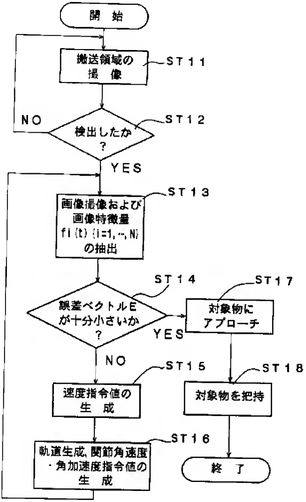
[Drawing 9]



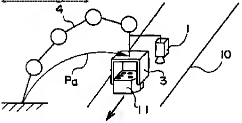
[Drawing 10]



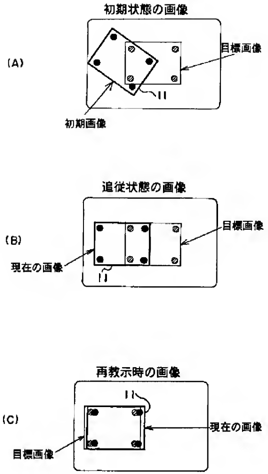
[Drawing 7]



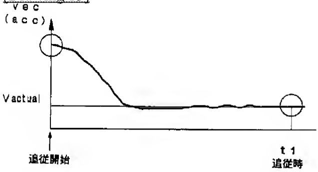
[Drawing 11]



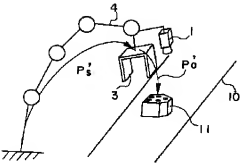
[Drawing 12]



[Drawing 13]



[Drawing 14]



[Translation done.]